

HIGHWAY RESEARCH REPORT

INVESTIGATION OF FIELD PRESTRESS GROUTING PROCEDURES

INTERIM REPORT

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STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

RESEARCH REPORT

NO. M & R 635117-1

Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration November, 1971

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819



November, 1971

Interim Report
M&R No. 635117-1
FHWA No. D03-12

Mr. Robert J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is an interim report titled:

INVESTIGATION OF FIELD PRESTRESS GROUTING PROCEDURES

By

R. E. Weaver and R. J. Freeman

Under the Direction of

D. L. Spellman
Principal Investigator

Under the Supervision of

R. F. Stratfull
Co-principal Investigator

Very truly yours,

A handwritten signature in dark ink, appearing to read 'J. Beaton', written over the typed name and title.

JOHN L. BEATON
Materials and Research Engineer

Attachment

REFERENCE:

Weaver, R. E. and Freeman, R. J., "Investigation of Field Prestress Grouting Procedures", State of California, Department of Public Works, Division of Highways, Materials and Research Department, Research Report No. 635117-1, November 1971.

ABSTRACT:

A study was made to determine what procedures were used for mixing and placing grout in prestressed, post-tensioned structures, and what problems might be encountered.

A number of field grouting operations were observed and mixing and placing data were gathered. Items given particular attention for this report were cement lumping, conduit type, and temperature.

It was determined that field problems could be expected to be reduced by at least one-half if specifications were strictly adhered to. Obviously lumpy or partially hydrated cement should not be used, grout void volume was about 20% greater for the rigid (solid) duct than for the flexible duct, and that an "end product" specification rather than limits would be desirable in regard to grout temperature.

KEY WORDS:

Grout, grouting cement, prestressed concrete, post-tension, bridges, corrosion, statistics.

ACKNOWLEDGMENT

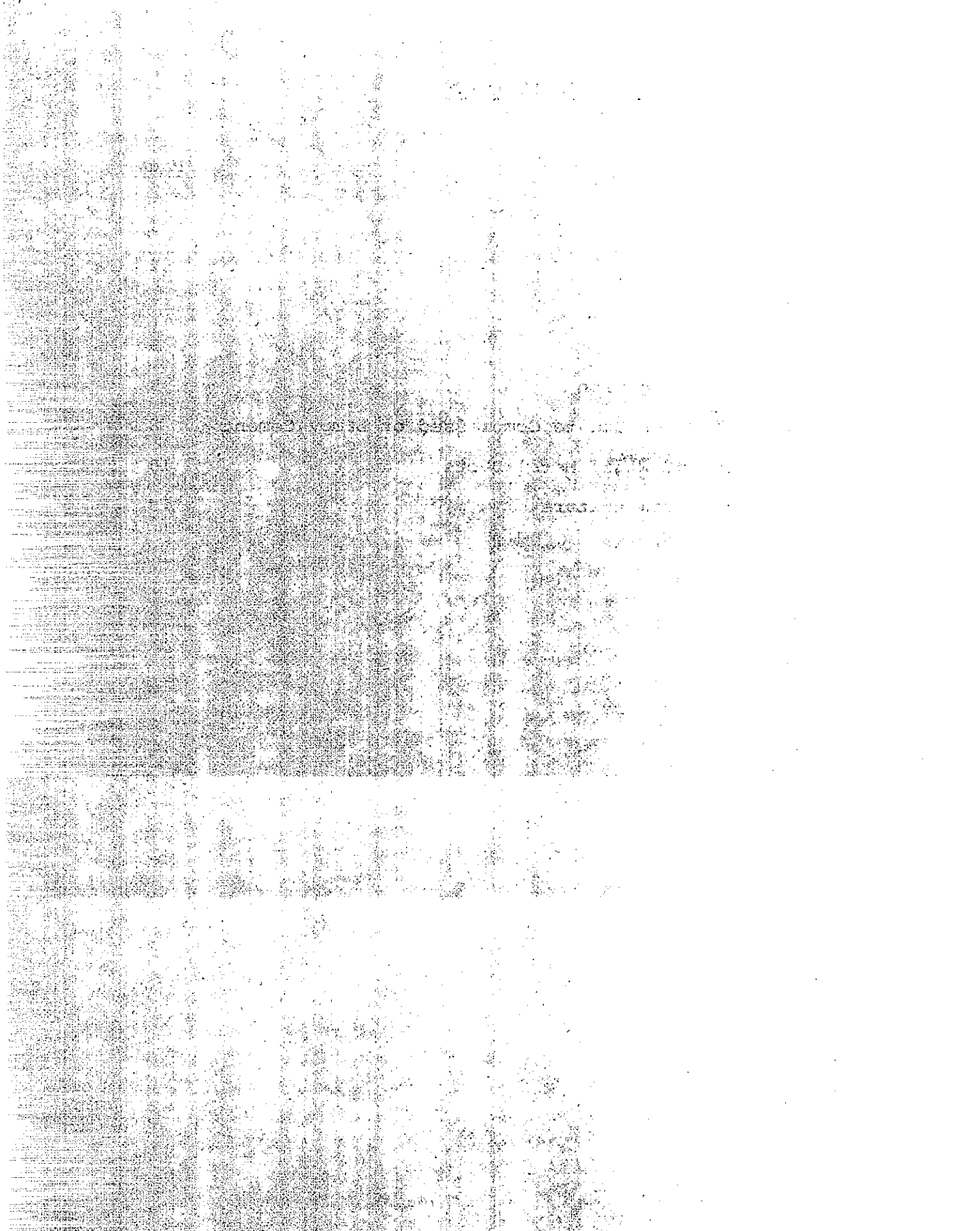
The authors wish to express their gratitude to all members of the Corrosion Unit of the Concrete Section past and present who contributed to the report. Special thanks to W. A. Winter, J. L. McCormick, R. L. Watkins, and M. Moser.

This project was performed in cooperation with the U. S. Department of Transportation, Federal Highway Administration, Agreement No. D03-12.

The opinions, findings, and conclusions expressed in this report are those of the authors and are not necessarily those held by the Federal Highway Administration.

TABLE OF CONTENTS

	<u>Page</u>
Introduction	1
Objectives	2
Summary and Conclusions	3
Test Results	5
A. Field Investigation	5
B. Lumps of Grout Due to Compressed or Lumpy Cement	8
C. Flexible and Rigid Metal Ducts	10
D. Effects of Temperature	10
Figures 1 to 14	
Bibliography	
Appendix	



INVESTIGATION OF FIELD PRESTRESS GROUTING PROCEDURES

INTRODUCTION

The corrosion of high-strength, prestressing steels in concrete became of serious concern with the increased use of prestressed concrete coupled with the fact that the grouting of ducts was not trouble-free. If the ducts were not completely filled with grout, then some degree of corrosion of the steel could be anticipated.

As a first step to better understand and control the corrosion of prestressing steel in post tensioning ducts in highway bridge construction, a number of field grouting operations were observed, and the batching and pumping data were recorded. After the data were grouped and analyzed, the results were used as guidelines for determining what could be expected in the field with respect to grouting time, pumping pressure, etc.

One of the most prevalent difficulties encountered in the field was the plugging of the ducts during pumping operations. To solve this problem where plugging was not the result of duct damage, it was necessary to obtain a better control of the grouting through a concise study of the properties and the influencing parameters of grout.

In addition to established test procedures; some new test methods for comparing grout properties were designed and used to evaluate the various physical properties of the grout.

The parameters investigated were cement lumping due to compaction or pack set, duct types, and temperature.

One factor should be pointed out. When this study began, it was believed that grout mixing was a simple task. As with many research projects, the performance of "simple tasks" may be obvious unless one tests the obvious. As a result, this project resulted in much "back tracking" that in effect was a study of how to mix grout.

OBJECTIVES

This study was initiated to establish a more effective control of corrosion of mild and high strength steel used in highway bridge concrete by insuring that the steel will be completely encased in neat cement grout.

This phase deals with determining (1) how grouting operations are presently performed, (2) what problems are encountered during grouting, and (3) what affects cement lumping, conduit type and temperature have on grout quality.

SUMMARY AND CONCLUSIONS

1. Duct Blockages - Pumping Pressures

It was found that approximately half of the problems encountered in the field were corrected by a careful control of grout quality. In general, the predominant field problem in producing the grout was insufficient mixing energy being imparted by the grout mixing equipment to achieve stability during the grouting operation.¹ Other problems usually involved irregularities or blockages in the flexible ducts. In most cases, when a restriction was encountered, if the grouting pressure was kept below about 150 psi, the duct could be filled with a stable grout. Conversely, duct blockages were observed when high grouting pressures were used. In effect, the high pumping pressure resulted in the "dry packing" of the duct with a semi-dry neat cement. Again, an "obvious solution" when encountering duct blockage, was to raise the pumping pressure, which only aggravated the condition.

The analysis of the field data presented in this report indicates that we have only considered some of the problems associated with the grouting of ducts. We have not fully investigated the problem of filling ducts when they are in excess of 500 feet in length. It should be noted that even though the grouting pressures and times were easy to measure, none of this work actually determined if the entire length of a duct was in fact, filled. This phase of grouting requires additional investigation.

2. "Lumpy Cement"

In simulated testing of "pack set" cement, any lumps of cement which were present in the test batches after 15 minutes of mixing were considered potentially troublesome. Most mixers used at construction sites were not as efficient as the one used in laboratory tests. Although it is probable that the lumps in the grout resulting from the use of pack set or compressed cement in the field would be larger and more numerous, highly compressed cement produced only 0.27% by weight of cement of lumps in the grout. It is concluded that any lumps in the grout which could cause grouting problems are the result of partial hydration of the cement and not simply the result of compressive forces. It therefore is advisable to prohibit the use of obviously lumpy or partially hydrated cement for grouting purposes. Cement manufacturers with the use of grinding/anti pack set agents are capable of providing free flowing cement. Lumps caused by moisture during storage are beyond the control of the manufacturer.

3. Rigid and Flexible Ducts

In the rigid and flexible duct test series, the volume of voids in the grout was about 20% greater for the rigid (solid) duct

than for the flexible duct. Because the rigid (solid) ducts were "airtight," it is believed that the gas which creates the voids, or other entrapped air, had remained entrapped in the grout. Conversely, the gas in the grout is believed to have dissipated or "bled off" into the surrounding concrete in the case of the "leaky" flexible ducts. (Rigid ducts which were tested were solid steel.)

4. Grout Temperature

The efflux times of various batches of grout, as measured by the flow cone, whose temperature at the end of a 20-minute quiescent period was between 70.5°F and 74.5°F, did not vary by more than 0.05-second. The plots demonstrated that temperature had more effect on efflux time after 20 minutes quiescence time than it had on the initial efflux time. In effect, grout temperature affected the initial efflux time to a minor degree as compared to the efflux time after a 20-minute period of quiescence. Based upon the lab test data, the pumping characteristics of grout in the field should not be significantly affected between a grout temperature range of 70°F and 90°F.

It should be emphasized that all parameters other than temperature known to affect efflux time were held constant in the tests from which the equations were derived. These parameters were (1) mixing energy, (2) water-cement ratio, (3) brand of cement. It is known that temperature of grout can affect the amount of air entrainment.

It seems probable that optimum grout temperature is very nearly 73°F. Optimum temperature is defined as that temperature at which the efflux time of the grout is at a minimum when all other variables are constant.

For laboratory mixing where temperature was to be eliminated as a variable, grout samples having a temperature between 71°F and 75°F were deemed satisfactory. It was assumed that unless greatly significant, the incorporation of grout temperature limits in construction specifications would be undesirable. A better approach would be to specify "end product" properties.

TEST RESULTS

A. Field Investigation

1. Field Grouting Procedures:

In the earliest stages of the field investigation it was noted that there was very little detailed data on how to control grouting operations. There were no specifications before 1960 to control grout quality and pumping. The only control in the California Standard Specifications from 1960 to 1964, with a numerical value, was the pumping pressure. It was specified that the Contractor's pumping equipment be able to produce 100 psi of pumping pressure and the grout be composed of "neat cement" and water.

At the present time, the grouting equipment generally used consists of a mixer that contains a separate mixing and holding tank, and two pumps, one of which is a stand-by. Also, the standard specifications currently require that a screen be present to remove any extraneous material that might interfere with pumping. Previously the screen was most useful for the removal of lumps of unmixed cement that most likely was the result of inefficient mixers. However, with the new and more efficient mixing equipment, it is not likely that grout will contain unmixed lumps of cement, although it is probable that lumps may still be present because of build up of cement on the sides of the mixing tanks.

Until 1964, prestressing ducts were flushed with water prior to grouting. From 1964 until 1969, slaked lime water was used for flushing. The development of strand type tendons precluded the need for flushing and it is presently discouraged because of the difficulty of removing all flushwater.

Early in the investigation it was observed that the water/cement ratio of the field mixed grout varied between 4.5 and 6.5 gallons per sack of cement. As the result of cooperative work with contractors and the Bridge Department, the maximum water/cement ratio of the grout now specified is 5.0 gallons/sack.

Grout quality is currently controlled by the use of a slightly modified flow cone test, Calif. Test Method No. 541, which evolved from the Corps of Engineers test method CRD-C-79-58.

It should be noted that for complete corrosion protection it is an absolute necessity that the entire duct be filled with good quality grout. To assure that all the voids were filled without decreasing the grout strength excessively, it was necessary to control the amount of admixture used in the grout because when certain admixtures were used in too large a quantity, the result

was a severely set retarded and low strength grout. In general, this reduction in grout strength could not be predicted, but was obvious from the abnormal appearance and prolonged setting time of some grouts. In addition, the longer the set is retarded, the greater the bleeding period of the grout. Thus, voids can be found in ducts as a result of the accumulation of bleedwater at the top of the duct.

2. Analysis

Fourteen field grouting operations were observed, and some data were collected from each. The batching and the pumping data were separated and the mathematical means of the batching data are given in Table 1.

Table 1
Grout Batching Data - Mean Values

Water/Cement Ratio (Gal/Sack)	Efflux Time At Duct Injection (Sec)	Efflux Time At Duct Ejection* (Sec)	7-Day Compressive Strength (psi)
4.75	11.3	11.9	1580

*Grout obtained from end of duct opposite injection end

If individual pairs of variables in the analysis of the pumping data were highly divergent, only the means of these variables were reported.

In general, the data shown were obtained by means of a regression analysis. Standard deviations, standard errors of the estimate, and means were determined.

In the field investigations, the rigid and flexible ducts varied in length from 40 to 700 feet, and the water/cement ratio varied from 4.5 to 6.5 gallons per sack of cement. The means of the pumping variables for the overall average length of duct of 182 feet are shown in Table 2.

Table 2
Field Pumping Variables - Mean

Flushing Time, min. (per Duct)	Grouting Time, min. (per Duct)	Pumping Pressure of Grout (psi)	
		Initial	Final
2.44	12.25	29.1	77.8

The means for the pumping pressure when a blockage was encountered were 230 psi for the flushing water and 193 psi for the grout. For the pumping variables, the best correlation was found to be between the length of the duct and the time it took to grout the duct. The following linear regression equation was derived from data from 10 of the 14 field grouting operations observed.

$$T = 0.021 L + 3.72$$

Where: T = time to grout duct in minutes

L = length of duct in feet

The mean for T was equal to 7.56 minutes with a standard deviation of 3.38 minutes, and the mean for L was 182 feet with a standard deviation of 145 feet. The standard error of the estimate for equation (1) was 1.59 minutes.

A relationship was also found to exist between the ratio of the diameter of the duct divided by length of the duct and the time it took to grout the duct. This relationship was developed from tendons of from 40 to 700 feet in length and from 2.37 to 4.50 inches in diameter.

The following linear regression equation limited to the 40-700 foot ducts was derived from data from 8 of the 14 field grouting operations observed.

$$T = -277 C + 12.6$$

Where: T = time to grout duct in minutes

C = ratio of diameter of duct in inches,
divided by length of duct in feet

The mean and standard deviation of T were 7.75 minutes and 4.12 minutes respectively. The mean and standard deviation of C were 0.0213 and 0.0147 inch per foot respectively. The standard error of the estimate was 2.67 minutes.

A linear regression was performed between length of duct and the change in pumping pressure from the initial to the final grout pumping pressure. In the field, the observed pumping pressure (excluding end effects due to the anchorage) varied from 18 to 82.5 psi. The following linear regression equation was derived from data from the 14 field grouting operations.

$$\Delta P = 0.174 L + 5.38$$

Where: ΔP = change in pumping pressure in psi

L = length of duct in feet

(L Limited to 40-700 feet)

The means and standard deviations for ΔP and L were 44.4 and 29.7 psi and 225 and 135 feet respectively. The standard error of the estimate was 19.7 psi.

A linear regression was also performed between a ratio of the pressure of the flushing water divided by the length of the duct. The resulting equation was derived from data from 5 of the 14 grouting operations.

$$T_f = -4.82 K + 3.29$$

Where: T_f = time to flush duct in minutes (4)

K = ratio of flushing pressure divided by length of duct in psi per foot

The means and standard deviations for T_f and K were as follows:

	Mean	Standard Deviation
T_f , Time to Flush	2.21	1.34
K, Ratio of Pressure per Foot	0.224	0.224

Again, it should be noted that although the correlation was good, the standard error of the estimate of 0.963 psi per foot gives a wide band about the line of equation (4). To decrease the confidence band more field data would be required.

B. Lumps in Grout Due to Compressed or Lumpy Cement

1. Test Procedure

Phase II of Laboratory Test Procedures³ was followed. Each batch consisted of 2.38 gallons of grout with a water-cement ratio of 4.75 gal./sk. of cement mixed at approximately 550 RPM for a maximum of 30 minutes. The grout mixer was a 1/2-inch drill equipped with a quad epoxy blade.

A 1725 ml. sample was taken every 5 minutes during mixing to measure the efflux time and observe the size and number of lumps.

Six batches were mixed; three test batches using 50% of compacted cement briquettes as "lumps," and three identical control batches using 100% uncompressed cement. Briquettes of cement were made by compressing samples of 1100 gm at a maximum pressure of nearly 7200 psi in a steel cylinder 4 inches in diameter by 5 inches long. The resulting briquettes were 2.5" x 4" in diameter and had a unit weight of 131 lbs./cu. ft. The test batches of three basic mixes were (1) without an admixture in the grout, the cement was first compressed with a force of 7200 psi then immediately released, (2) with an admixture in the grout, the cement was first compressed with a total force of 7200 psi, then immediately released, and (3) with an admixture in the grout, the cement was first loaded to 7200 psi, then held for 15 minutes and released. The test results are shown on Table 3.

Table 3
Effect of Added Compressed Cement

*Test Group Number	Percent Compressed Cement	% of Admix.	Mixing Time, Minutes					
			5	10	15	20	25	30
			Time of Efflux, Seconds					
1	0	0.00	28.1	15.0	14.4	13.8	13.8	13.4
2	50	0.00	14.9	14.9	13.7	13.4	----	13.1
3	0	0.75	11.7	11.9	11.9	11.8	11.6	11.5
4	50	0.75	11.4	11.2	11.2	11.3	11.6	11.3
5	50	0.75	11.7	11.7	11.6	11.5	11.4	11.6
6	0	0.75	11.9	11.6	11.5	11.7	11.7	11.7
			Lumps Retained on #16 Sieve as % of Total Cement					
6	0	0.75	0.008	0.001	0.001	0.002	0.002	0.004
5	50	0.75	0.28	0.25	0.29	0.26	0.29	0.27
			Lumps Passing #12 Sieve as % of Lumps Retained on #16					
5	50	0.75	77	85	84	83	85	89

*Groups 2 and 4 were loaded to 90,000-lb. (7200 psi) maximum at 60,000-lb./min. and released immediately on reaching maximum. Group 5 was loaded similarly, but the maximum was held for 15 minutes.

2. Analysis

The lumps retained on the No. 16 sieve were approximately spherical and nearly uniform in size. About 80% of the lumps retained on the No. 16 sieve would pass a No. 12 sieve. There were some lumps present in both the test and control batches. Therefore, all lumps found in mixed grout were not necessarily the result of using specially compressed cement.

Test Batch No. 5 contained many times the number of lumps contained by control Batch No. 6, but the total was still only about 0.27% by weight of the cement or about 4 oz. per sack.

The test batches containing compressed cement exhibited a slightly lower viscosity than the control batches. The reason may have been that the lumps of cement in the test batches did not absorb as much water as the normally dispersed cement and thereby increased the effective water/cement ratio.

It is of interest that the 7200 psi at which the cement was compressed was equivalent to the pressure that would be exerted on the bottom sack of a stack of cement 15,000 sacks high. Therefore, lumpiness sometimes observed in sacked cement appears to be related to hydration or lack of use of an anti pack-set agent during manufacture rather than stacking of the sacks of cement. The cement used may have had an anti-pack setting agent inter-ground with it, thus preventing the kind of packing sometimes observed in sacked cement.

C. Flexible and Rigid Metal Ducts

1. Test Procedure

Five 40-inch lengths of flexible metal conduit were cast in concrete simulating flexible duct embedded in a concrete structure. In addition, five 40-inch lengths of steel pipe of the same diameter were also fabricated simulating rigid, impervious ducts. One specimen from each of these groups was filled under 60 psi pressure with grout from each of five different batches. After curing for 7 days, each specimen was sawed into 6 equal sections and the differences in the hardened grout were observed.

2. Analysis

In general, there was little difference between the two types of ducts when they were filled with a nonexpanding grout. Expanding grout seemed to fill the flexible metal duct better than the solid pipe. In the flexible duct, the hardened grout was full of small voids caused by the evolved hydrogen gas, and the continuous void at the top of the duct was relatively small. In the solid pipe, the small gas voids did not form, and the continuous void at the top of the duct was larger. The reason for the discrepancy in the void system is believed to be the result of the physical characteristics of the ducts. In the flexible ducts, gas could leak through the lapped walls and escape into the concrete. In the solid duct, the gas could only accumulate at the top of the duct as a result of gravity, not being able to escape, preventing maximum expansion of the grout.

D. Effects of Temperature

1. Test Procedure

In the three following test series, Phase III of the Laboratory Test Procedures was followed with variations in the mixing speed, water-cement ratio, and batching temperatures.

In the first test series, the water-cement ratio was 4.75 gallons per sack of cement and the mixing speed was 1200 rpm. The mixing equipment was the specially designed 5-gallon bucket with four baffles and the quad epoxy blade.

In the second test series, the same 1200 rpm mixing speed and mixing equipment were used with the water-cement ratio reduced to 4.5 gallons per sack of cement.

In the third test series, the water-cement ratio was 4.5 gallons per sack of cement and the mixing speed was increased to 1300 rpm. The mixing equipment was the specially designed 5-gallon bucket and the three rod blade with three matching baffles.

In all three test series, the unconfined and confined volume change, the 7, 14 and 28-day compressive strength, the unconfined bleeding, and the initial and 20-minute efflux times were measured.

2. Analysis

In the first test series, eight batches were mixed at various temperatures ranging from 61 to 135°F. The results are shown in Figures 1 through 5. Of the six batches mixed at 78°F or higher, the higher temperature resulted in higher viscosity and stiffening rate, less bleeding and shrinkage, and greater strength. Of the three batches mixed at 78°F or colder, the lower temperature also resulted in higher viscosity and stiffening rate, less bleeding and shrinkage, and greater strength. There appeared to be an optimum grout temperature somewhere between 65 and 80°F considering viscosity and rate of stiffening.

In order to confirm the observations of the first test series, a second test series of six batches was mixed at temperatures between 60 and 109°F. The water-cement ratio of these batches was reduced to 4.5 gallons per sack of cement from the 4.75 gallons per sack of cement used in the first test series because it seemed likely that the effect of temperature on viscosity would be more pronounced in the drier grouts.

The results of the second test series were similar to those of the first test series. In Figures 6 through 11, it can be seen that the batch mixed at 71°F had a lower viscosity, stiffening rate, and compressive strength, and exhibited greater bleeding and shrinkage than did the other batches. The optimum temperature to yield the least viscosity and the least rate of grout stiffening was apparently between 60 and 89°F. Based on the second test series, and considering both test series together, the optimum grout temperature would appear to be between 70 and 80°F. See Figure 12.

After analyzing the data of the first two test series, the third test series was designed. The information sought was the precise optimum temperature and the quantitative effect of any deviation from this optimum. The primary dependent variable was the efflux time after 20 minutes of quiescence, since the effect of temperature

on stiffening rate is greater than it is on the initial viscosity. The primary independent variable was the temperature of the grout sample.

Thirty-five batches of grout were mixed at temperatures ranging from 48 to 116°F. The cement used was a brand of Type II which had in the past shown the least variation in chemical and physical properties. The water-cement ratio was held at 4.5 gallons per sack of cement. Test data were mathematically analyzed and the resulting equation indicated an optimum sample temperature of 74°F with a minimum efflux time of 12.4 seconds after 20 minutes of quiescence. A temperature of 4°F above or below optimum (74°F) caused the efflux time to be 0.1-second greater than minimum, and a 14°F temperature difference caused a 1.0-second rise in efflux time.

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MEMORANDUM

TO : THE SECRETARY

FROM : THE ATTORNEY GENERAL

SUBJECT: [Illegible]

DATE: [Illegible]

RE: [Illegible]

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Figure 1

EFFLUX TIME VS QUIESCENT TIME AT
VARIOUS BATCH TEMPERATURES
TEST SERIES 1

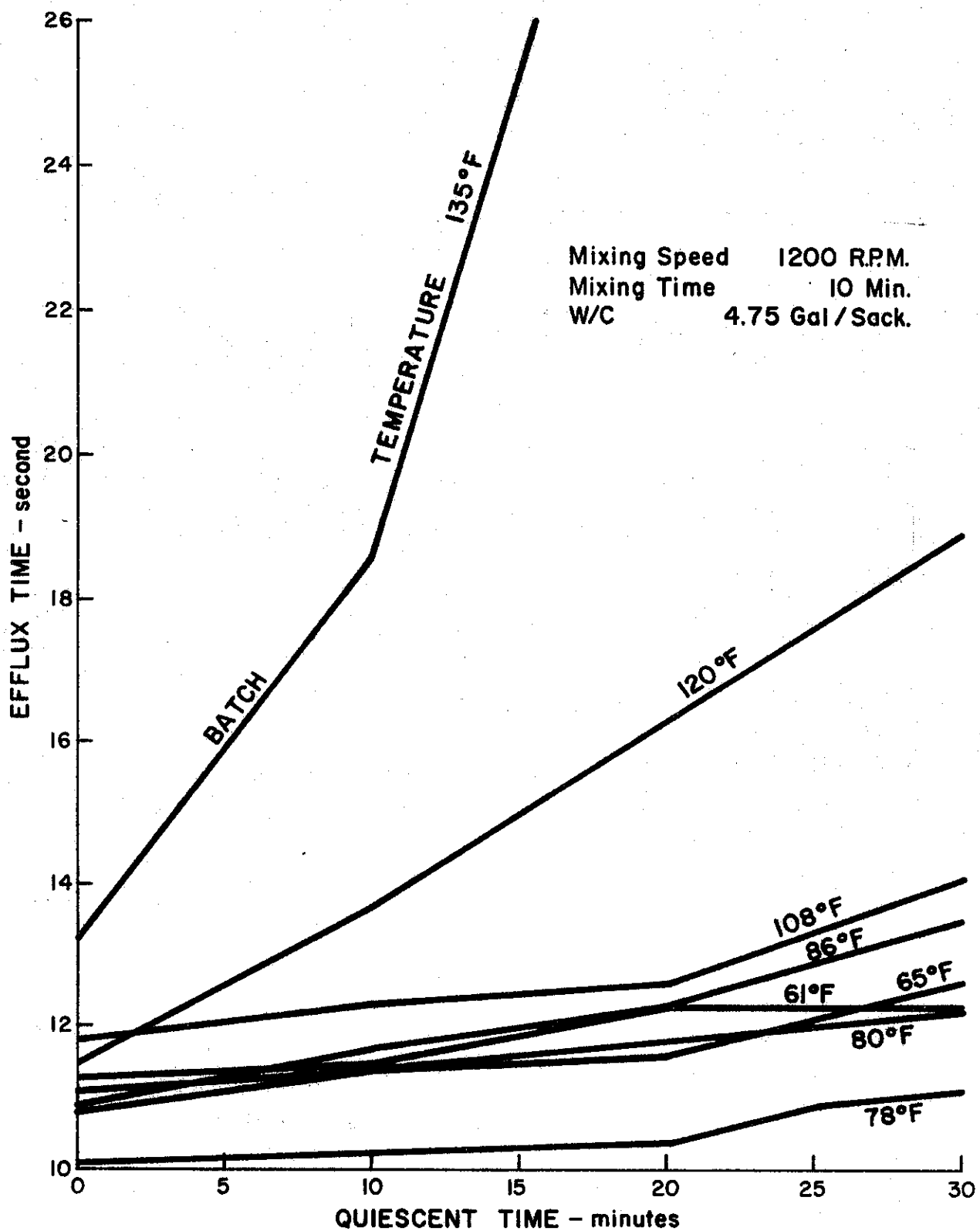


Figure 2

MAXIMUM BLEEDING VS BATCH TEMPERATURE

Test Series 1

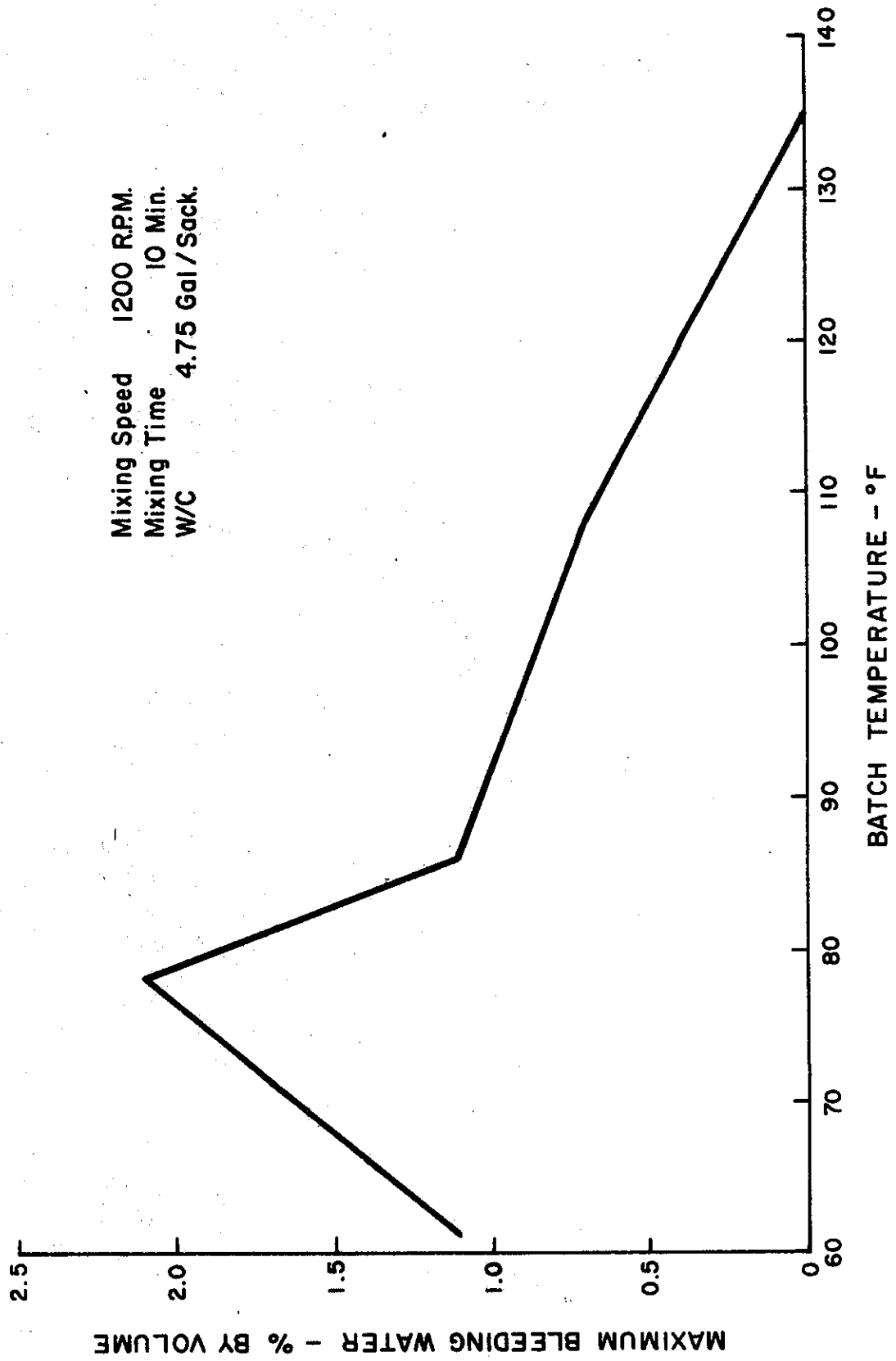


Figure 3

UNRESTRAINED SHRINKAGE VS BATCH TEMPERATURE

Test Series 1

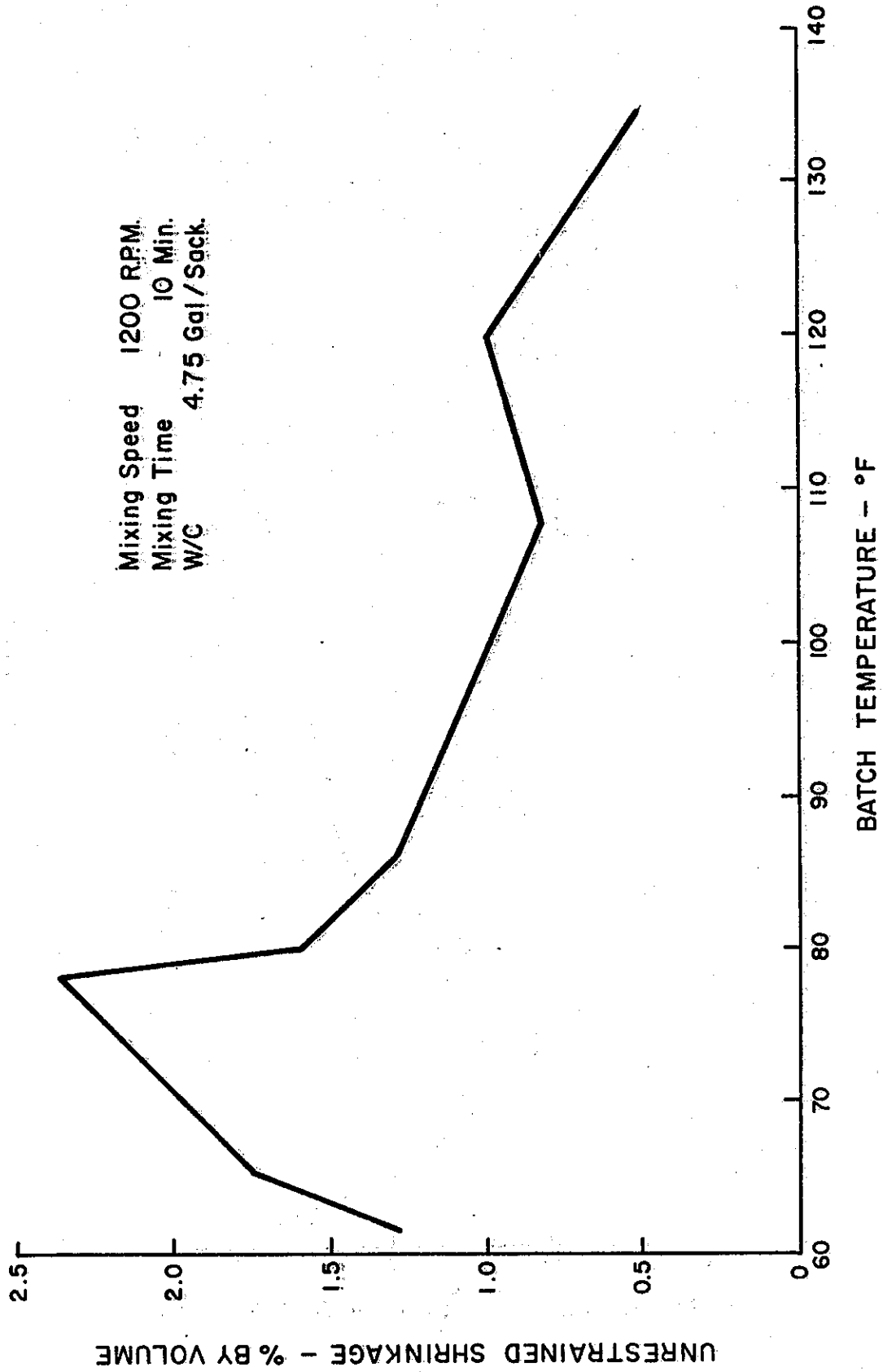


Figure 4

RESTRAINED SHRINKAGE VS BATCH TEMPERATURE

Test Series I

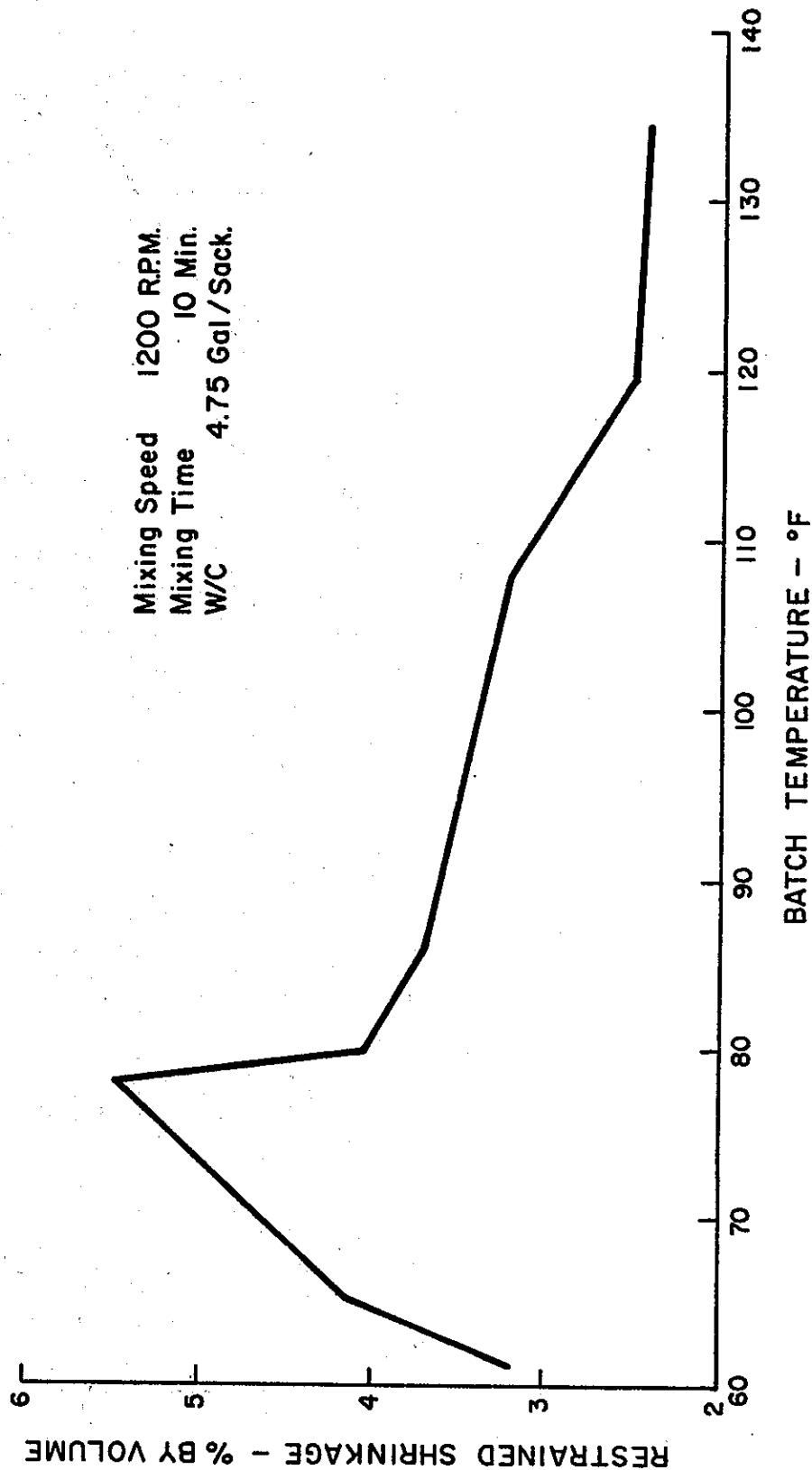


Figure 5

28 DAY COMPRESSIVE STRENGTH VS BATCH TEMPERATURE
Test Series 1

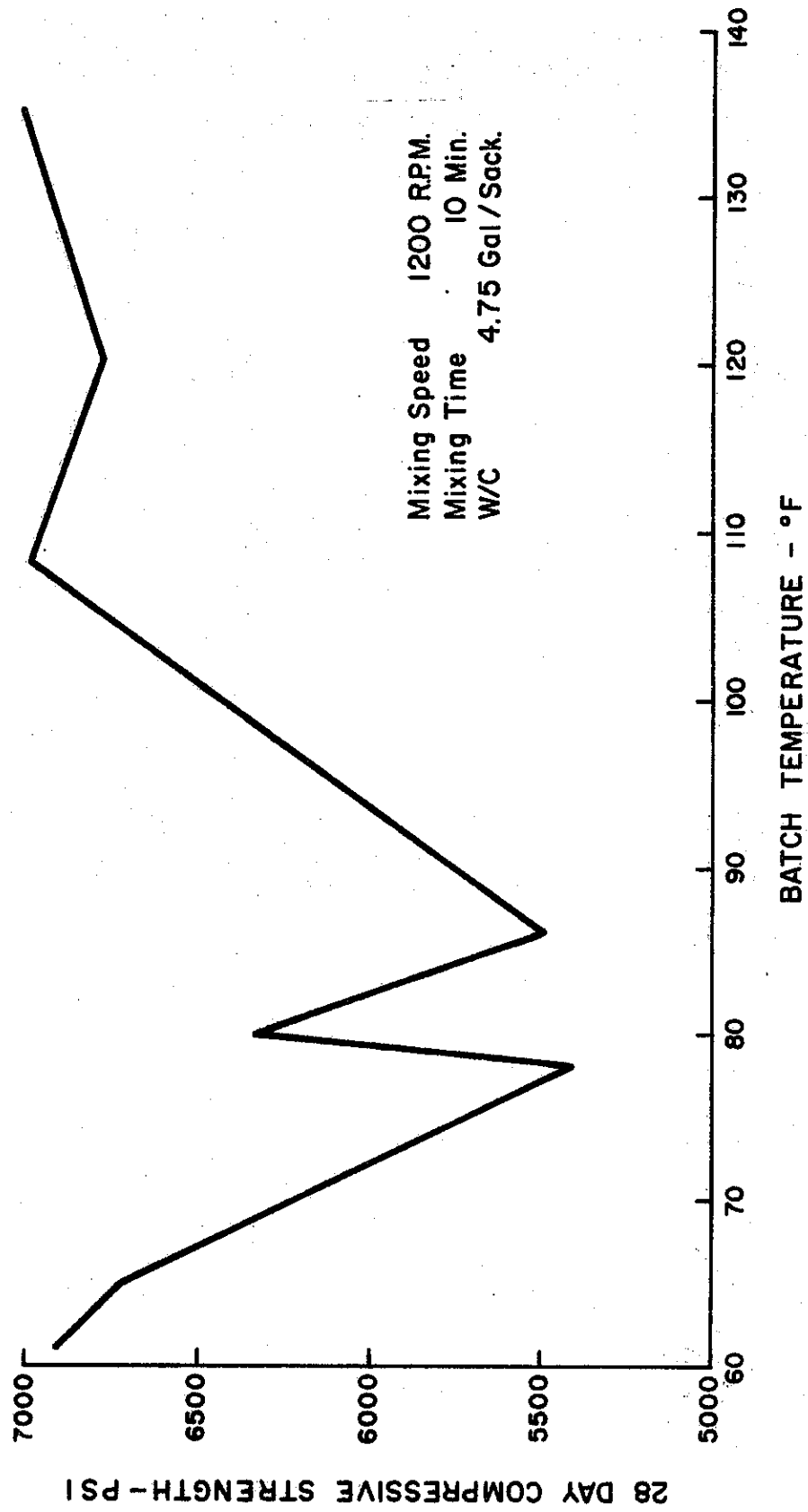


Figure 6

EFFLUX TIME VS QUIESCENT TIME AT
VARIOUS BATCH TEMPERATURES
TEST SERIES 2

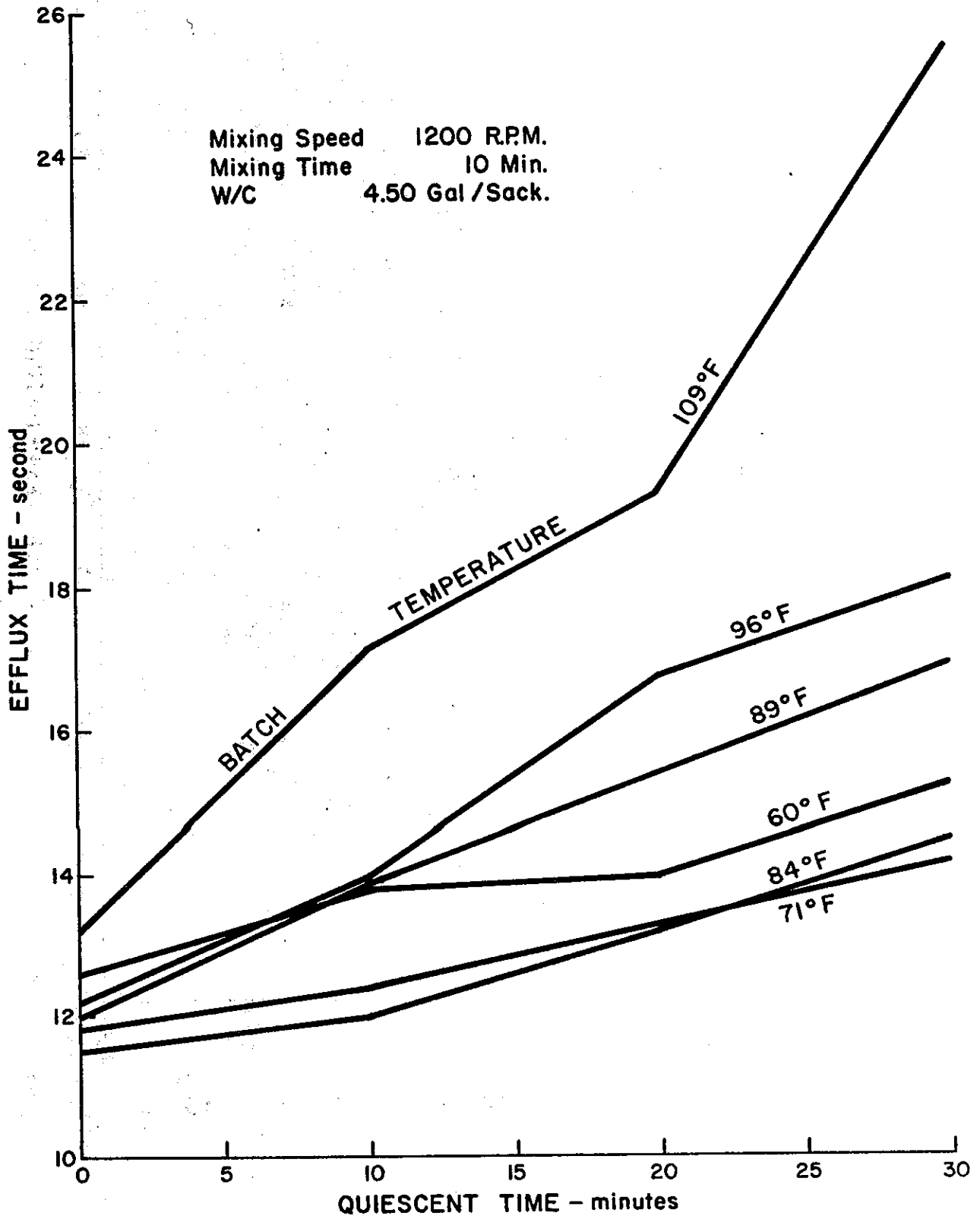


Figure 7

MAXIMUM BLEEDING VS BATCH TEMPERATURE
Test Series 2

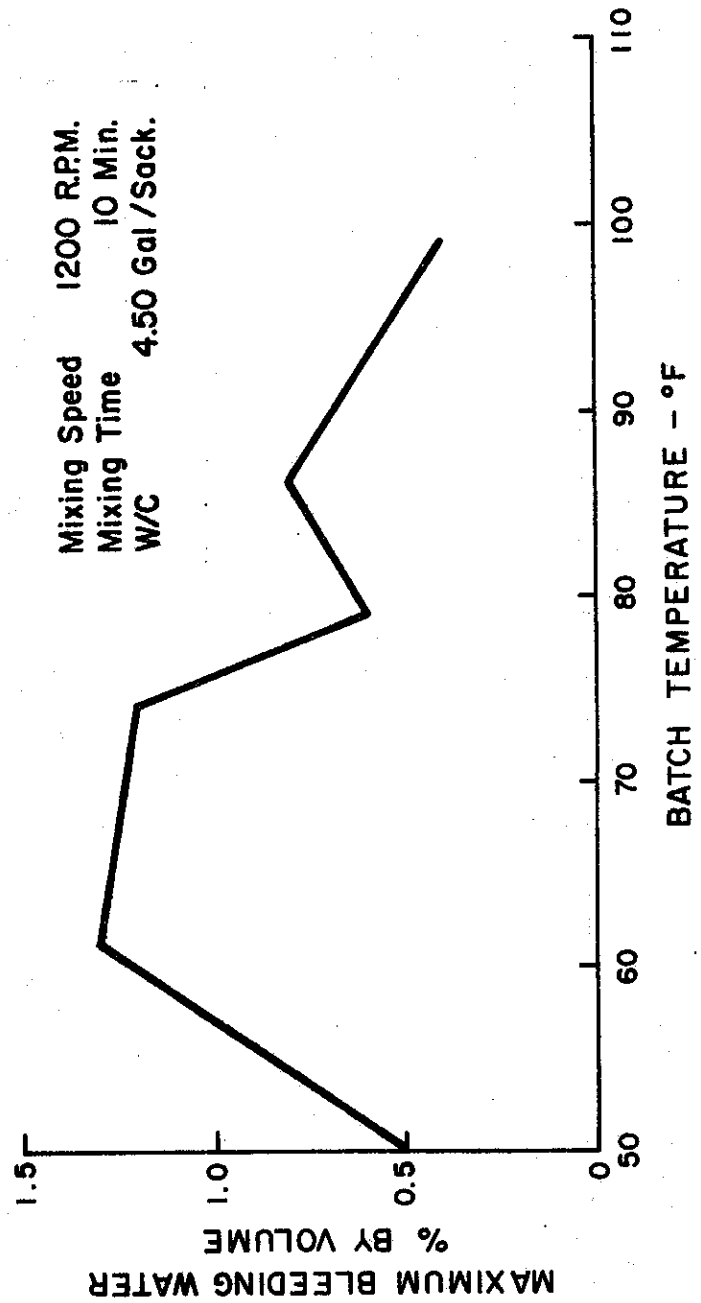


Figure 8

UNRESTRAINED SHRINKAGE VS BATCH TEMPERATURE

Test Series 2

Mixing Speed 1200 R.P.M.
Mixing Time 10 Min.
W/C 4.50 Gal / Sack.

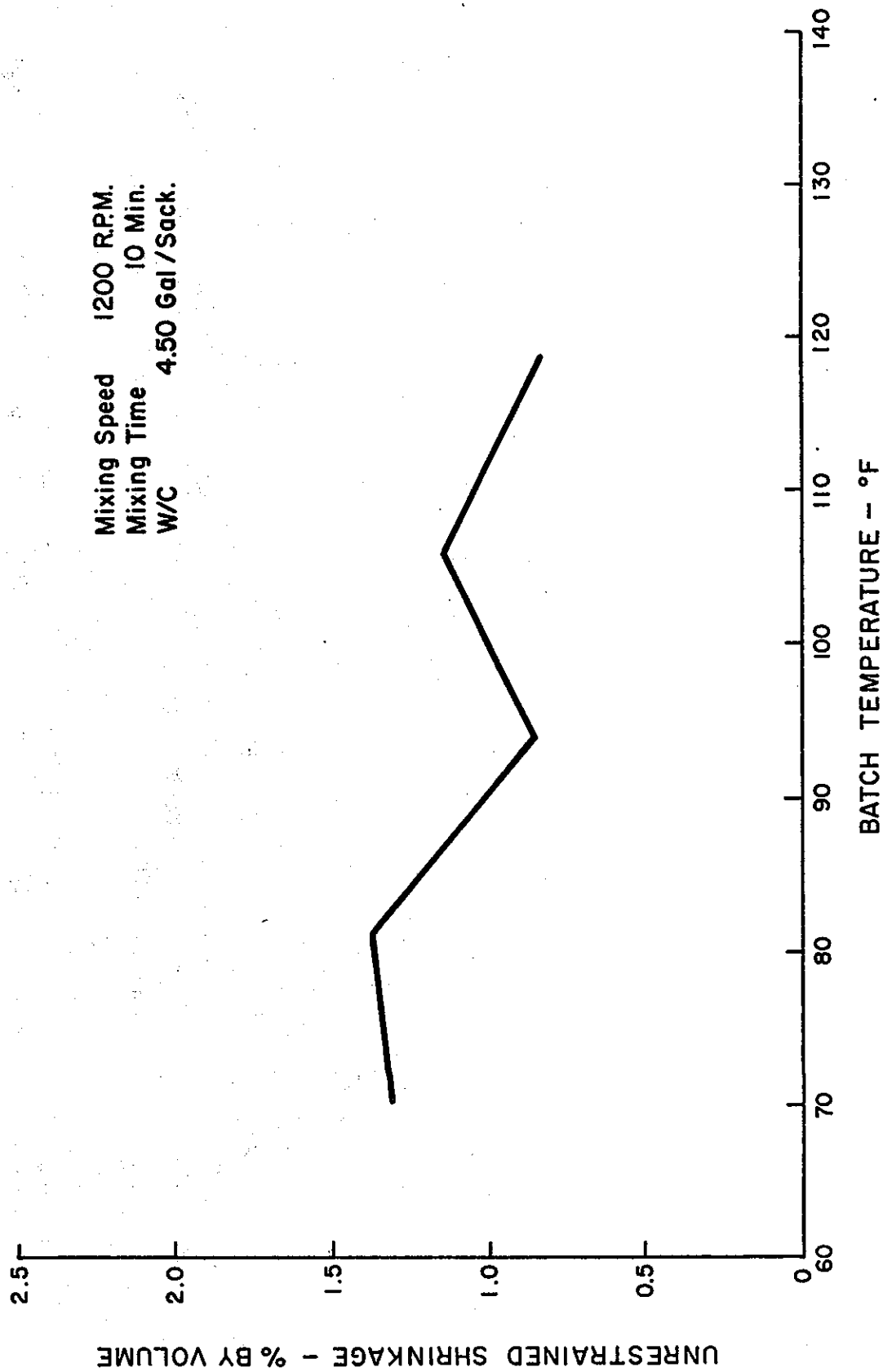


Figure 9

RESTRAINED SHRINKAGE VS BATCH TEMPERATURE
Test Series 2

Mixing Speed 1200 R.P.M.
Mixing Time 10 Min.
W/C 4.50 Gal/Sack.

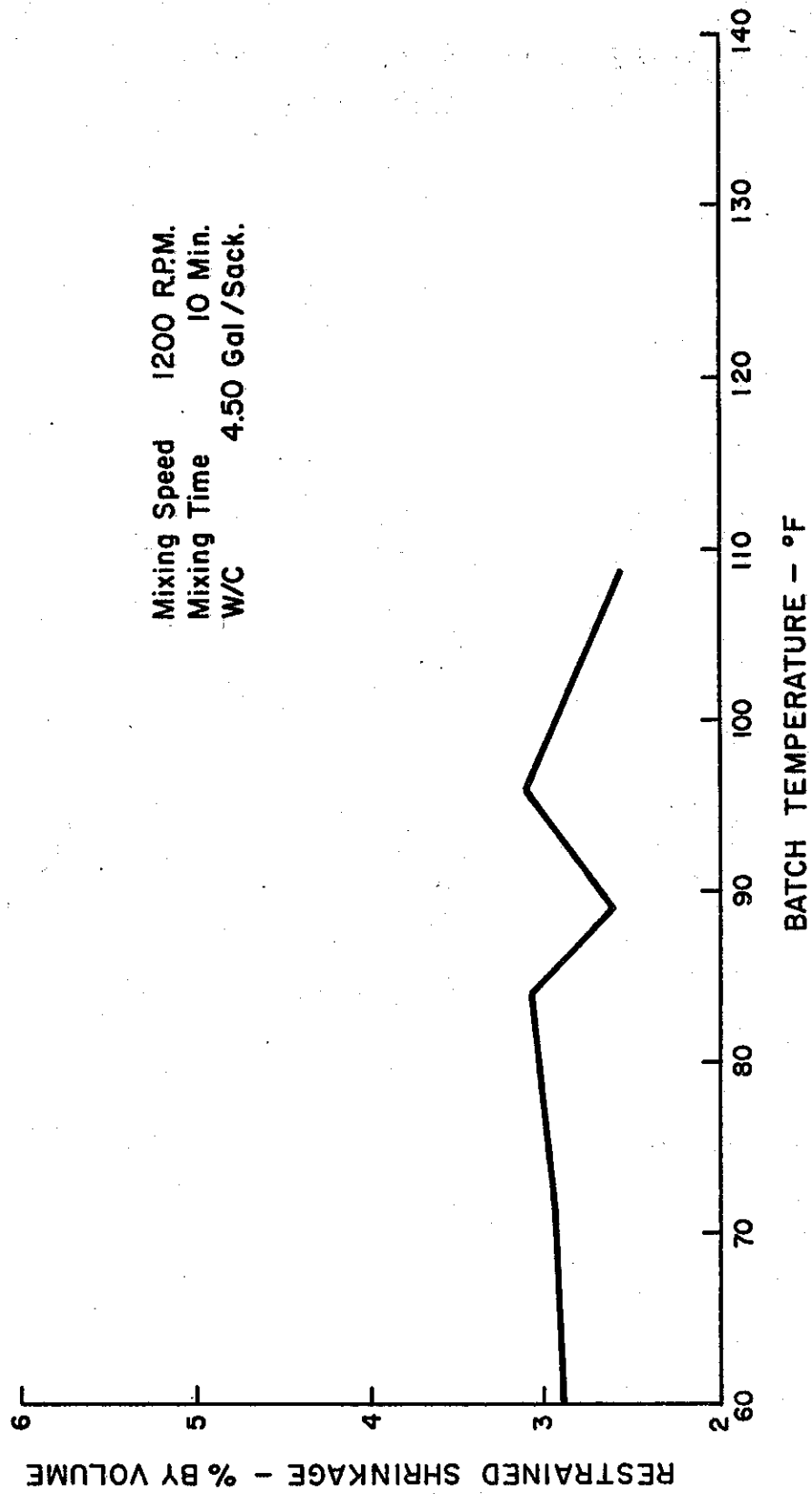


Figure 10

14-DAY COMPRESSIVE STRENGTH VS BATCH TEMPERATURE TEST SERIES 2

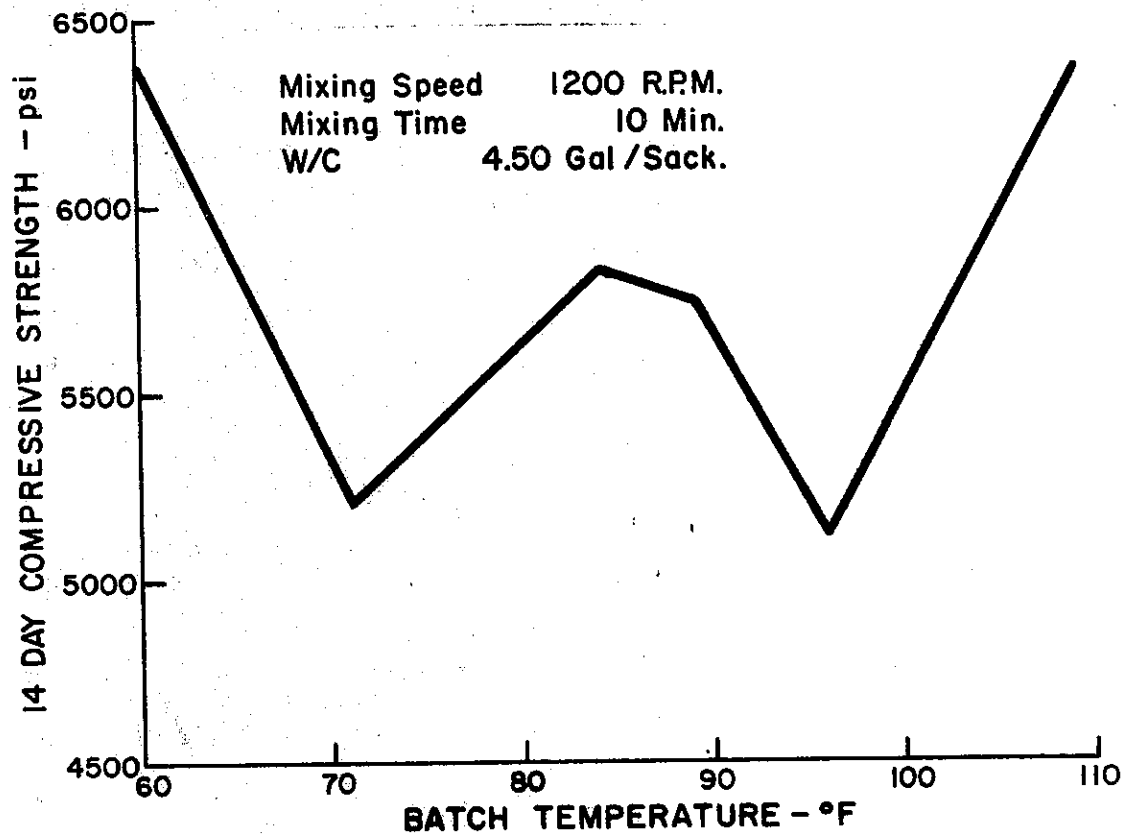


Figure 11

28 DAY COMPRESSIVE STRENGTH VS BATCH TEMPERATURE
Test Series 2

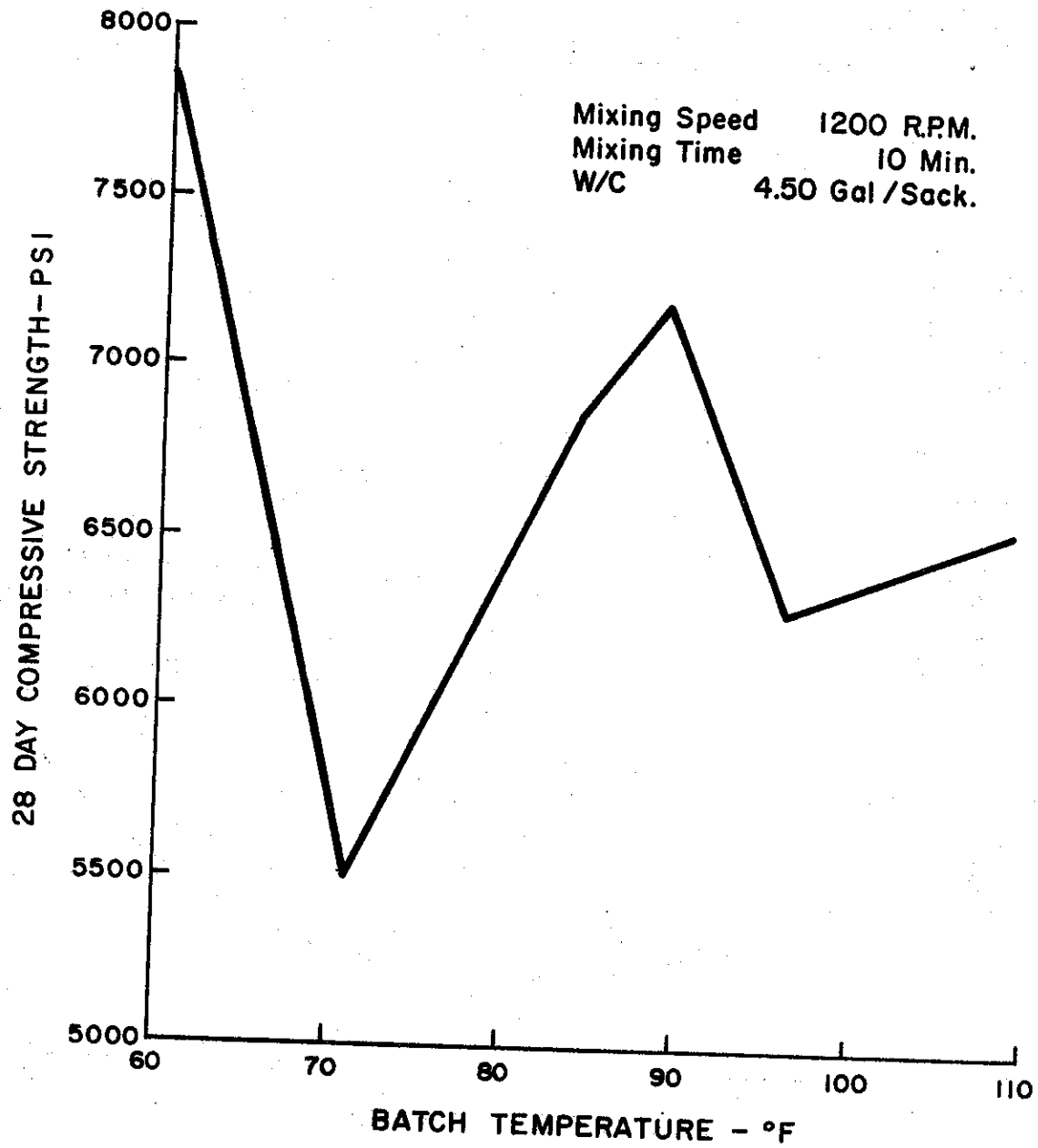
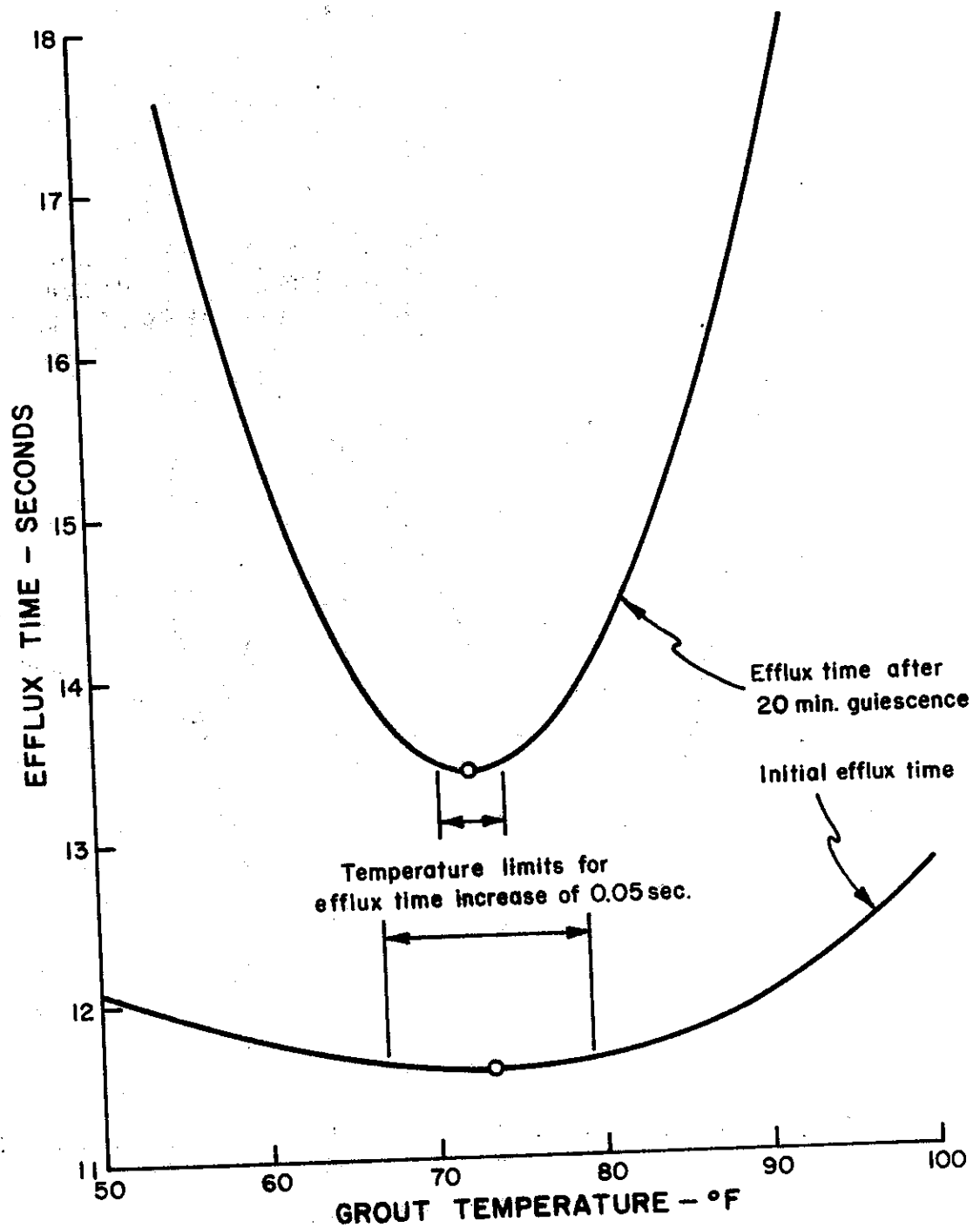


Figure 12

EFFECT OF TEMPERATURE ON EFFLUX TIME



METHOD OF TEST FOR FLOW OF GROUT MIXTURES (FLOW CONE METHOD)

Scope

The procedure to be used for determining the flow of grout mixtures is described in this test method.

Procedure

A. Apparatus

1. Flow cone and supporting ring conforming to the dimensions indicated in Figure I.
2. Stop watch having a least reading of not more than 0.1 second.
3. Rubber stoppers, Size 00.
4. Sample container of 4 liter min. capacity (a 6"x12" concrete mold is adequate.)
5. Suitable stand for supporting ring. (5-gallon paint bucket may be used, see Figure II.)

B. Sample

The test sample shall be approximately 4000 ml of grout.

C. Determination of Efflux Time

1. Dampen flow cone and allow any excess water to drain. Place the cone in the supporting ring and insert the rubber stopper.
2. Level the cone, then pour the grout from the sample container into the cone until the grout surface is level with the bottom of the three holes in the side of the cone.

3. Remove the stopper and start the stopwatch simultaneously.

4. Stop the stopwatch at the first break or change in the continuous flow of grout from the discharge tube. Record the indicated time of efflux to the nearest 0.1 second.

5. Dispose of the grout sample, rinse the equipment.

D. Determination of Efflux After Quiescence

1. Fill cone with grout as previously described, using remainder of 4000 ml sample.

2. Allow grout to rest in cone for 20 minutes \pm 15 seconds from the instant the cone is filled to the time the efflux time is to be measured. After the 20-minute quiescent period, determine efflux time as described previously in Section "C".

3. Record efflux time of the grout.

E. Precautions

The cone must be placed in a location that is free from vibration.

The cone must be kept clean from cement buildup especially in or near the orifice and nozzle.

REFERENCE

A California Method

End of Text on Calif. 541-A

FIGURE I

GROUT FLOW CONE

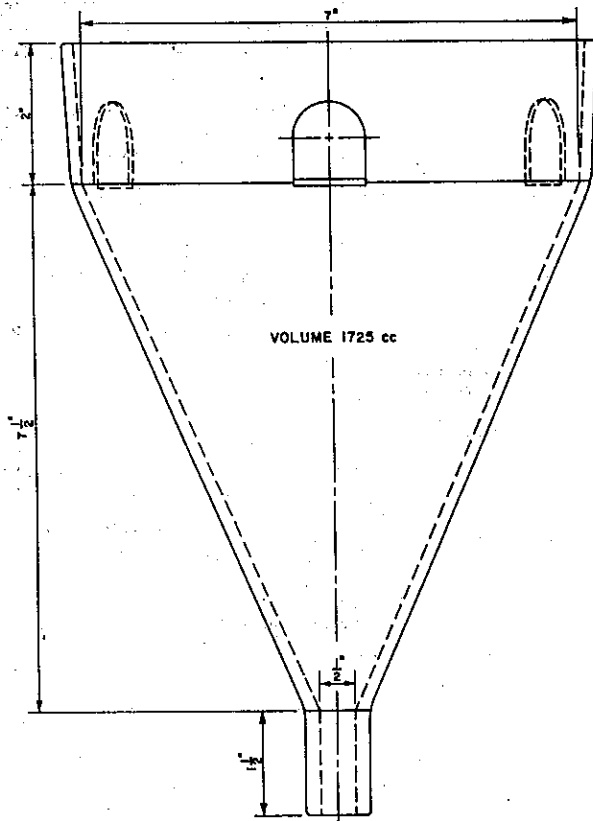


FIGURE II

GROUT EQUIPMENT

